

## §66. A Study of Particle Transport Based on the Balmer- $\alpha$ Line Profile

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The Balmer- $\alpha$  line profile has been observed with high wavelength resolution for discharges aiming at getting higher plasma performance with respect to  $T_i$ ,  $n_e$ , and  $\beta$ , which are the ion temperature, the electron density, and the ratio of the plasma pressure to the magnetic field pressure, respectively.

Figure 1 shows the line profiles obtained. In the all

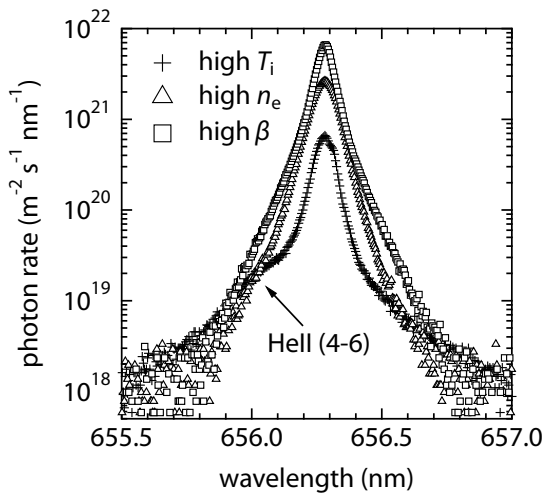


Fig. 1: Balmer- $\alpha$  line profiles measured for a high- $T_i$  discharge (plus), for a high- $n_e$  discharge (triangle), and for a high- $\beta$  discharge (square).

three cases the line profile is found not to be approximated with a single Gaussian function. Actually, a Gaussian function would be a parabola when the magnitude is shown in the logarithmic scale and that is not the case for the results in Fig. 1. Here, the line profile is regarded as a superposition of various Gaussian components having different widths and magnitudes. Since the Gaussian width is directly related to the atom temperature  $T$ ,  $T$  is used instead of the line width hereafter.

Mathematically, the line profile  $I(\lambda)$  can be expressed as an integral transform such as  $I(\lambda) = \int_0^\infty g(T)f(\lambda, T)dT$ , where  $f(\lambda, T)$  represents the Gaussian function of the temperature  $T$  and  $g(T)$  is its fraction in the whole profile. It is readily shown that the equation above can be rewritten as the form of Laplace transform after replacement of several parameters.

The Balmer- $\alpha$  line shows a large variety of profiles as shown in Fig. 1 depending on the conditions of the discharge. The high- $n_e$  discharge shows a peaked  $n_e$  profile and a flat  $T_e$  profile. The central  $T_e$  and  $n_e$  at the timing of the line profile observation are 0.3 keV and  $4 \times 10^{20} \text{ m}^{-3}$ , respectively. The high- $T_i$  and high- $\beta$  discharges have a peaked  $T_e$  profile and a flat  $n_e$  profile. The central  $T_e$  and  $n_e$  for the high- $T_i$  discharge are 3.5 keV and  $9 \times 10^{18} \text{ m}^{-3}$ , respectively, and those for the

high- $\beta$  discharge are 0.4 keV and  $2.5 \times 10^{19} \text{ m}^{-3}$ , respectively.

It is noted that the hump shown at around 656.0 nm for the high- $T_i$  discharge is due to the HeII ( $n = 4-6$ ) line. Since other profiles are also potentially influenced by the same line, the wavelength range longer than the line center is only used in the following analysis.

We have carried out numerical inversion of the Laplace transform <sup>1)</sup> of the line profile and derived  $g(T)$  <sup>2)</sup>. The temperature dependence is then translated to the radial distribution, where the ion temperature profile which is approximated by the  $T_e$  profile is used, so that the radial profile of the photon emission rate  $\epsilon(R)$  is evaluated from  $g(T)$ . The ionization rate  $S(R)$  and the neutral influx  $\Gamma(R)$  are finally derived with the help of collisional-radiative model calculation.

Figure 2 shows  $\Gamma(R)$  obtained. The influx  $\Gamma$  at the out-

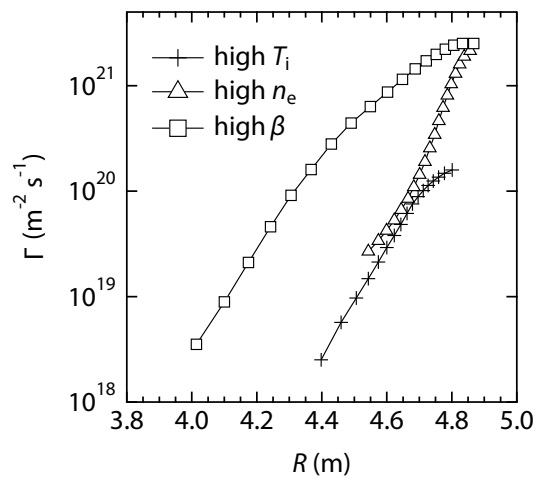


Fig. 2: Radial profile of inward atom flux derived from  $g(T)$  for the discharges analyzed here.

most location is in the similar magnitude between in the high- $\beta$  discharge and in the high- $n_e$  discharge, while in the high- $n_e$  discharge the decay is much faster and  $\Gamma$  in the core region is much smaller. Since the absolute  $n_e$  is lower in the high- $\beta$  discharge, its higher  $\Gamma$  values leads to a smaller value of the particle confinement time.

The relative  $\Gamma$  profile is similar between in the high- $T_i$  discharge and in the high- $\beta$  discharge while the magnitude is approximately one order smaller in the former. However,  $n_e$  in the high- $\beta$  discharge is larger only by a factor of three. This result also leads to a smaller particle confinement time in the high- $\beta$  discharge.

These results are understandable because the central magnetic field strength in the high- $\beta$  discharge is 0.41 T which is rather weaker than 2.539 T in the high- $n_e$  discharge and than 2.75 T in the high- $T_i$  discharge.

1) Bellman, R. E. et al.: Numerical Inversion of the Laplace Transform, Elsevier, New York (1966).

2) Goto, M. et al.: Nucl. Fusion **51**, 023005 (2011).